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APPLICATION  
FOR  
UNITED STATES  
LETTERS PATENT

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For: SYSTEM, METHOD, AND APPARATUS FOR  
PORTABLE DESIGN, DEPLOYMENT, TEST,  
AND OPTIMIZATION OF A  
COMMUNICATION NETWORK

Docket No.: 02560028AA

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**SYSTEM, METHOD, AND APPARATUS FOR PORTABLE  
DESIGN, DEPLOYMENT, TEST, AND OPTIMIZATION OF A  
COMMUNICATION NETWORK**

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**DESCRIPTION**

**BACKGROUND OF THE INVENTION**

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*Field of the Invention*

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The invention generally relates to a miniature portable system for design, deployment, test, and optimization of a communications system, such as an indoor or campus-wide wireless or wired communication network. A handheld computing platform is used for the collection and display of communication signal properties, the manipulation of communication system components in a communications network design, and the prediction and optimization of communication systems during design, deployment, or maintenance operations.

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*Description of the Related Art*

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In recent years the use of wireless communication technology, such as cellular phone networks, has greatly increased. Moreover, it has become common to implement wireless communication systems within buildings or large facilities comprising several buildings. Examples of typical wireless communication systems are local area networks (LAN),

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attenuation, data throughput time is also a function of transmission distance and signal obstruction (e.g. walls, doors, partitions), as well as multipath propagation and the specific radio modem design.

Various signal property measurement acquisition tools and systems  
5 have been developed to aid in the design of wireless communication systems such as PenCat™, Walkabout PCS™ and TEMS Light.

LCC International Inc. offers the PenCat™ as a pen-based collection and analysis tool for wireless communication design that runs on a small hand-held tablet computer. The PenCat™ system enables a  
10 user to roam about a building, take signal property measurement data at a location in the building using a receiver linked to the tablet computer, and link the measured data to that building location on a computer map representing the building by tapping the appropriate portion of the map on the computer screen with a stylus pen. The building map can be entered  
15 into the PenCat™ system by either scanning blueprints, sketching the building within the application, or importing from another source. PenCAT uses two dimensional bit maps to model the building environment.

Safco Technologies, Inc. offers the Walkabout PCS™ system as a  
20 portable survey coverage system for use in indoor or outdoor wireless communication system design. Similar to PenCat™, the Walkabout PCS™ system utilizes a hand-held computer linked to a receiver for measuring signal properties at a given location and linking the measured property data to that location represented on a stored computer map. Also  
25 similar to the Safco Walkabout is the Agilent 74XX indoor measurement system, which also uses a bitmap floor plan.

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In addition to the above-discussed wireless communication systems verification tools, various wireless communication system prediction tools have also been devised such as Wireless Valley Communications Incorporated's Predictor<sup>TM</sup> and Ericsson Radio Quality Information Systems' TEMS. Predictor<sup>TM</sup> allows a wireless communication system designer to predict the coverage area of a particular wireless system in a building or across multiple buildings. Predictor<sup>TM</sup> creates a computer simulation using a computer stored building or facility database and a defined transceiver location and type within the database. Based on the building configuration and building material properties defined in the database a prediction of the coverage area of the wireless system is extrapolated by site-specific propagation whereby rays drawn between the transmitter and receiver and three-dimensional building



5 While the above-mentioned design and verification tools have aided wireless system designers in creating indoor wireless communication systems using building drawings and linking data measurements to building drawings, none of the devices, except for InFielder™ and Predictor™, incorporate three-dimensional building  
10 drawings to enhance the design process. Further, the above-mentioned devices and systems lack the ability to track a roving user while autonomously or passively measuring or collecting network performance data while uploading or downloading the data to a remote monitoring location. These capabilities may be required for installation and ongoing  
15 monitoring and management of wireless devices for global network access.

There have been recent innovations in the use of portable handheld computers as information collection devices for field maintenance and service. River Run Software has produced the OnSite software that uses a Geographic Information System (GIS) to display street maps of a desired location. Using custom designed information gathering forms, OnSite allows a field operator to go directly to a location, gather information, and either return with that information or send the gathered data over a wired or wireless communications link to another computer. Autodesk, Inc. also produces a software tool called OnSite that, although independent of River Run's OnSite, accomplishes a similar task. Autodesk's OnSite allows a

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## SUMMARY OF THE INVENTION

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spacing to form a mesh or blanket. Each vertex corresponds to a single point within the 3-D environment. Thereafter, a communication system performance prediction model is run whereby the computer displays on the screen at each vertex of the mesh the predicted performance values, for instance, received signal strength intensity (RSSI), network throughput, packet latency, packet error rate, distributed power levels, quality of service, bit error rate, frame error rate, signal-to-interference ratio (SIR), and signal-to-noise ratio (SNR), provided by the communication system just designed. The display is such that the computer adjusts the elevation and/or coloring including characteristics such as saturation, hue, brightness, line type and width, transparency, surface texture, etc., of each vertex relative to the surrounding vertices to correspond to the calculated performance values. The coloring and elevation may correspond to the same calculated performance value or to different calculated performance values. For example, elevation may correspond to received signal strength intensity (RSSI), and color may correspond to signal-to-noise ratio (SNR), or any other of a variety of calculated performance parameters. The user is able to specify boundaries for this display in terms of selecting the range of elevations, colors, or other aesthetic characteristics from which the vertices of the mesh are assigned. Alternatively, the system can automatically select limits and ranges for the heights, colors, and other aesthetic characteristics. The result is a region of fluctuating color and elevation representing the changing wireless system performance throughout different portions of the modeled 3-D environment. The region may be viewed overlaid with the 3-D environment.

An important focus of this invention is the use of miniature, hand-held (e.g., Palm), portable computers which have been adapted to provide a technician with a display of all or a portion of a three dimensional model, allow for on-site manipulation of the model (e.g., adjustments as to choice of equipment, placement in the space, and orientation) to obtain performance prediction and other valuable information. These hand-held portable client computers also provide a measurement capability for measuring various communications performance parameters within the space which measurements can be utilized either in the hand-held, portable client computers and/or be transmitted to one or several server computers, which may or may not be similar hand-held portable computers. During testing, actual performance values may be measured and entered into the hand-held computer (or gathered directly if the hand-held computer is equipped with an appropriate measurement device) and either sent to one or more of the servers for display, logging, and tuning the prediction models or for use in the prediction models on board the hand-held computer. In addition, the hand-held portable client computers may be equipped with global positioning technology or other location equipment which allow the technician to locate himself within a building or campus. Used in conjunction with the measurement features, the technician can have the portable hand held computer sample various measurements either overtly or passively in the background and have them paired to location information which will assist in modeling the space and making various optimizing changes in the deployed system. Many other advantages in deploying, testing, and optimizing communication networks may be

achieved using the hand-held portable client computers, either alone or in combination with the server computers. Preferably, the hand-held portable client computers will allow for the selection of various buildings in a campus environment and display various floor plan layouts for multi-story buildings selected by the technician.

A method for representing sophisticated 3-D vector databases of buildings and campuses of buildings is described. With this system, a field technician can carry the hand-held computer into the field and use the displayed information to select placement of the components and build the physical communication system. Another advantage of the system is that field engineers can modify the plan while building the physical system. Modifications such as removing, adding, or editing positions or parameters of components can be entered into the hand-held computer acting as a client and can be transmitted to the server where an updated environment and prediction model can be calculated and sent back to the hand-held computer. Alternatively, calculations can be performed at the hand held computer, the modifications can be made, and the updated model can then be uploaded to the server. Thus, this system allows for bi-directional data flow between the client and server. Other data, such as measured or predicted network performance parameters, files, photographs, notes, and general information may be embedded or sent separately with the model.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

The foregoing and other objects, aspects and advantages will be better understood from the following detailed description of the preferred

embodiments of the invention with reference to the drawings, in which:

Figure 1 is a plan view of a portable, hand-held computer;

Figure 2 is a schematic view of a visual campus database to be displayed on the portable, hand-held computer;

5           Figure 3 is a schematic of the system of the present invention which includes at least one portable computer and at least one server computer which can exchange data and other information;

Figure 4 is a flow diagram showing the opening sequence used when obtaining files for use on the portable computer;

10           Figure 5 is a schematic diagram which illustrates the double buffering concept which is used to speed up the information displayed to the technician;

            Figures 6a and 6b are display screens presented on the portable, hand-held computer which show editing of an antenna configuration in three dimensions;

15           Figure 7 shows the use of a translation handle to move a component such as a base station to a new location within a floor plan presented on the screen of the hand-held computer in 3-D;

            Figure 8 shows the ability to alter the position and layout of a component such as a cable as it is displayed on a floor plan presented on the screen of the hand held computer;

20           Figure 9 is a schematic diagram illustrating the communication links between the portable handle client computer and the server computer; and

25           Figure 10 is a schematic diagram showing the portable hand held computer equipped with a measurement device.

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**DETAILED DESCRIPTION OF THE PREFERRED  
EMBODIMENTS OF THE INVENTION**

Using the present invention, it is now easier than ever to design,  
5 deploy, test, optimize, and maintain communication networks in and  
around multi-floored buildings, campuses of multi-floored buildings, and  
environments including outdoor 3-D terrain. The present method is a  
significant advance over the prior art in the breadth of information  
presented to the user while operating a portable handheld computer. Using  
10 the embodiment presented, an engineer can cover the complete cycle of  
design, deployment, test, and maintenance for a communications network.

To facilitate navigation within a multi-floored building or campus  
of multi-floored buildings or in an outdoor 3-D environment, the present  
invention provides for a computer aided design (CAD) or other similar  
15 system to assist in creating graphical drawings representing the building  
system. Being able to smoothly navigate within a physical environment  
including a building or campus of buildings is critical for the  
aforementioned cycle of design, deployment, test, and maintenance of  
communication networks. In a large system with complex network assets,  
20 a sophisticated information management system is especially necessary  
during the design and deployment and maintenance stages.

An exemplary embodiment of the invention runs on a portable  
handheld computer. The current embodiment uses the Palm IIIC portable  
handheld computing device, as shown in Figure 1, from Palm Computing  
25 Inc, of Santa Clara, CA. One skilled in the art will see that many other  
portable handheld computers could be used as hardware platforms while

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staying within the spirit of the present invention. Some examples for other potential hardware platforms would be cellular phones, other personal digital assistants (PDAs) running the PalmOS operating system (OS) from Palm Computing, Inc. of Santa Clara, CA, Pocket PC s running the  
5 Windows CE OS from Microsoft, Inc. of Redmond, WA, and in some cases larger pen tablet computers running a member of the Windows operating system family or another powerful OS such as Linux or Be.

The hand-held computer 10 is programmed to provide on the display 12 two-dimensional layouts and three-dimensional images of a  
10 building or campus in which a communications network is or will be deployed. As an example of the type of software which could be used in the practice of this invention, Wireless Valley Communications, Inc. of Blacksburg, VA. markets a software product named SitePlanner® which is a tool suite that has computer aided design (CAD) facilities that can  
15 provide the layout of buildings and 3-D terrain, insert morphological objects such as trees, shrubbery, or human populations, and place network components. In a preferred embodiment, a 3-D environmental database is created in SitePlanner® to model the physical environment under study, as disclosed in co-pending application Serial No. 09/218,841, filed on May  
20 26, 1999, the complete contents of which is herein incorporated by reference. The resulting definition utilizes a specially formatted vector database comprising lines and polygons that represent physical objects within the environment. The arrangement of lines and polygons in the database corresponds to physical objects in the environment. For example,  
25 a line or other shape in the database could represent a wall, a door, a tree, a building wall, or some other physical object in the modeled environment.

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SitePlanner® has been designed as a wireless communications planning, design, test, and optimization tool suite. The powerful CAD facilities that SitePlanner uses to model buildings are not unlike the capabilities of most common CAD tools. As such, one skilled in the art  
5 could easily see how other CAD packages could be used to generate similar 3-D representations of multi-floored buildings and campuses of multi-floored buildings.

The current invention presents a method for compactly representing the database of physical objects within the environment. One  
10 novel aspect of the invention is the use of a 3-D environment database designed for a portable handheld computer. Current portable handheld computers lack the vast amounts of hard disk storage, random access memory (RAM), or processor speed common to desktop Personal Computers (PC s). The present invention provides a method for  
15 representing sophisticated 3-D vector databases of buildings and campuses of buildings in a compact space suited for a portable handheld computer system.

The term *vector* format is used here to mean a representation for a point in some logical space. In dealing with 3-D vector systems, three  
20 spatial coordinate axes, X, Y, and Z, are typically used to represent a point in space. The vector database specifies the boundaries of the vector space used, often giving a transformation matrix to convert points in the database vector space with a physical units system such as inches or meters. To represent lines, circles, or other compound shapes, a vector  
25 database uses sequences of vector points. For instance, a line in 3-D is usually specified with a starting point and ending point. Polygons are

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where to draw a line, what color to use when drawing the line, how thick the line should be drawn, etc. Each of these opcodes uses different operands to inform the software reading the WPD file how or where to draw the object. For instance, along with the opcode for drawing a line, the operands specify the beginning and ending vector points for the line. When an application is reading a WPD file, the opcodes are parsed sequentially. That is, the opcodes come in a chronological order according to how objects should be displayed on the screen or commands should be executed.

When storing opcodes and operands in a WPD formatted file, binary-only data is written. The present invention differs from some prior art that allows ASCII strings to represent instructions or opcodes. By using a binary representation, the WPD files will be significantly smaller. On top of the compact binary representation, the WPD file may be compressed using the LZ77 compression technique. The LZ77 compression algorithm is a standard mechanism for exploiting redundancy in data streams. More information on the LZ77 compression algorithm can be found in Ziv J., Lempel A., A Universal Algorithm for Sequential Data Compression, IEEE Transactions on Information Theory, Vol. 23, No. 3, pp. 337-343.

The WPD specification, in terms of its use of binary opcodes and operands to compactly store data, is not a new concept. Significant prior art can be exhibited: the Windows Metafile (WMF) specification from Microsoft, Inc. of Redmond, WA; the Drawing eXchange Format (DXF) from Autodesk, Inc. of San Rafael, CA., the Drawing Web Format (DWF) also from Autodesk, Inc. of San Rafael, CA, and many others, some of

which even apply compression techniques such as LZ77 and others. However, none of the prior art contemplates use on a portable handheld computer nor does previous art provide a measure for display of a three dimensional environment that includes integration of networking  
5 components, and communication system performance when providing remote monitoring through a server.

The present embodiment preferably exists in part as a module within the SitePlanner® tool suite. This module within SitePlanner® provides functionality so that a user can export a .dwg database of a 3-D  
10 environment into a compact WPD file which conserves memory and bandwidth when compared with .dwg and other drawing formats. To export a .dwg file, each building, tree, floor, plant, wall, elevator, etc. must be translated from the representation in a SitePlanner® .dwg file into the corresponding representation within the WPD file. Such a translation is  
15 preferably done using a look-up table (LUT) where representations in the .dwg format have a corresponding representation using WPD opcodes and operands. In the current embodiment, each building is exported into a unique WPD file. The exported file is ready to be packaged for use on a portable handheld computer.

20 In addition to fully supporting a vector format for representing a physical 3-D environment, the current embodiment supports users who only have raster images of the environment or building. To construct a 3D representation of a multi-floored building, a user may use a collection of 2-D raster images stacked together. While consuming considerably more  
25 memory, it has been found that many users do not have access to electronic CAD drawings of a building, and are forced to use scanned

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blueprints or other raster images.

The present invention preferably employs a novel management feature termed the “visual campus database” to assist in organizing a campus of multi-floored buildings. Using the previously defined WPD format, a 2D pictorial representation, either vector or raster, can be used to display a campus of multi-floored buildings from a top-down view, as shown in Figure 2. When entering a building, the user views the display of the hand-held computer and taps or selects the pictorial representation of the desired building 14. In the present embodiment, a building hyperlink opcode is used to instruct the software in the hand-held computer where to find the WPD file associated with the selected building. Using a building hyperlink reduces memory usage and improves drawing time, two critical features for operation on a portable handheld computer.

15 In the current embodiment where a Palm IIIC portable handheld  
computer is used, a Palm DataBase (PDB) header structure must be placed  
at the top of each WPD file when it is first created. The PDB header tells  
the PalmOS what the name of the database is, the type of database, the  
application associated with the database, among other management  
20 utilities. In the case of the current embodiment, each WPD file is assigned  
a database type referred to as "WPDB" indicating Wireless Valley  
Communications Portable DataBase. The creator ID, that is the  
application associated with the WPD file, is given an alphanumeric tag  
indicating it will be employed on the hand held computer. In the preferred  
25 embodiment, a four letter tag is used for implementation on a Palm IIIC.

In the present embodiment, a WPD database, having had the PDB

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5     The selected building database is then opened for reading at block 32. By default the first floor of the building is drawn on screen at block 34. Note the user may use the visual campus database to represent any large outdoor environment, such as a city or a coverage area typically served by macrocellular wireless systems.

10            In the present embodiment, only one floor of each building may be displayed at a time. However, it will be understood by those of skill in the art that 3-D visualizations could be used to provide more information to the user. A list of floors in the current building is preferably provided to the user in the Graphical User Interface (GUI) on the portable handheld  
15            computer. As the user moves from one floor to another, the current floor may be selected from the list of floors.

The hand held computer and software can employ a method for drawing and storing the current floor known as double buffering, as shown in Figure 5. Double buffering involves drawing the current floor into an off-screen buffer in memory 36. In the present embodiment, the off-screen buffer may be larger than the primary display 12 size. Thus, the current view, or viewport 38, occupies a smaller rectangle within the off-screen buffer 36. The viewport 38 always has the same or smaller resolution size as the primary display 12. Using double buffering reduces flicker and apparent drawing times. To draw the active viewport 38 on the actual display screen 12, the Palm OS software development kit is used to copy

the data within the off-screen buffer into the display screen's buffer.

In the current embodiment, to pan around in a building floor, the user selects the pan button on the graphical user interface (GUI). Tapping on the screen and dragging the stylus around will cause the viewport 38 window location to change within the off-screen buffer 36. As the viewport coordinates change, the screen is updated by recopying the visible area onto the display. Zooming in and out of a drawing is implemented in a similar fashion. When the user selects a zoom tool button (either zoom in or zoom out) on the GUI and taps on the screen, the viewport window size is changed accordingly, and the screen is redrawn using the tapped location as the new center for the drawing. The maximum zoom level occurs when the viewport window is scaled such that the number of pixels in the display window matches the number of coordinate points in the WPD file contained within the active viewport window. User interface buttons 40 can be used to do the navigation described above. Alternatively, soft keys could be displayed on the screen of the portable computer 10 which would allow zoom and movement of the viewport 38.

20           The technique described above, as well as other comparable techniques, allows one to easily navigate within a complex system of multi-floored buildings.

Building material properties such as wall densities and material types, glass thickness, etc. or material manufacturer names and sources can be also embedded within the WPD file. When a building floor is viewed in the present embodiment, the user may select a building object and view the object's properties directly on the portable handheld computer 10. In



25 Preferably, the user can manage all network specific assets using a  
bill of materials from SitePlanner® as specified in pending application

09/318,842 filed May 26, 1999, the complete contents of which is herein incorporated by reference. In addition, asset management data such as physical condition, installation cost, component cost, depreciation, maintenance schedules, and important facilities management information may be stored and displayed. To view bill of materials information on the portable handheld computer 10, the embedded network components and their physical locations within the environment are extracted from the WPD file and linked into a list of assets. In the present embodiment, the user may view the list of assets by selecting View BOM within the "Tools" menu item on the hand held computer 10. A list of all the network components is displayed along with part information such as price, manufacturer, and performance characteristics. Simultaneously, the user may view the location of all such components within a 2-D or 3-D representation of the environment.

In addition to being able to display and manage a communication system's components, the present invention allows field engineers to modify a system's configuration while operating within the building or campus of buildings. Modifications such as removing, adding, or editing locations, positions or parameters of components are supported in the present embodiment. To remove a network component, the user simply taps or clicks once to select the object, and then specifies Remove Object from the Edit menu. To add a component, the user selects the Add Object from the Edit menu. A series of window dialogs, or forms, guides the user through the selection of a network component. The first few forms specify the general class of object such as wireless equipment, wired telephony component, optical fiber asset, etc. Later forms, based on the



general class of component selected, vary such that specific information can be entered. For instance, in a wireless communications system, a base station may be placed within the active floor. In the same system, an antenna or cabling system can be placed to connect with the base station.

5 Once components have been added to the building system, or if components already exist, the user may edit the configuration, layout, and properties of an object. To edit the network component properties, the user may tap or click on the object twice in succession, or, having tapped or clicked on the object once, choose the Properties command within the Edit menu. A list of the current objects' properties is displayed.

Where possible, the user may edit the object's configuration or properties. For instance, an antenna system may have a certain rotation in three dimensions. A preferred embodiment allows the user to specify a new rotation and orientation by choosing rotation angles from each of the three primary spatial axes, all while displaying the antenna system in a wireframe 3-D view, as shown in Figures 6a and 6b. Specifically, Figure 6a shows a three dimensional view where soft keys "x", "y" and "z" are used to edit the antenna configuration, and Figure 6b shows two 2D views with the soft keys "x", "y" and "z" being used to edit the antenna's configuration.

Other components may also be edited or moved throughout the displayed environment depending on the changeable parameters available for the selected object. The technique for making these edits will depend on the software being used on the portable computer 10. An important feature of this invention is that the technician is permitted to make changes in parameters, components, locations, and orientations of components, on

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displayed next to the base station. The user may click or tap on the box 46 and drag the pointing device around to specify a new location for the base station. Other components work in an identical fashion for merely translating the object.

Some components may be re-oriented on the display screen. For example, a cable system may be altered in the manner it is routed within a building. As shown in Figure 8, the user can be shown a solid box 48 at each vertex of the cable system 50. Tapping or clicking on the solid box and dragging the pointing device around causes the vertex location to change. For illustrative purposes, Figure 8 shows the translation handle 52 connected to vertex 54 of the cable which will allow this vertex to be moved from the wall 56. The end of the cable 50 is connected to component 58 which can also be moved as described above in connection with Figure 7. In a preferred embodiment, the user may additionally select a Force Size constraints option with the Options menu to force any changes to a cable system to use the existing lengths of cable. Other techniques may also be used for addressing the movement and/or repositioning of cables and the like. An important feature of this invention is that the cable position, or “proposed” cable position, is identified to the technician on his or her portable hand held computer, and he or she may re-position the cable into alternative positions based on his or her on-site assessment of the building or other structure or geographical area in which the cable will be located. As discussed in conjunction with Figure 7, and Figures 6a and 6b, this invention allows both the location and orientation to be altered on-site in a similar fashion, and still further, the invention allows for the selection of diverse components (e.g., selection of a

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changes made using the portable handheld computer 102 will be merged into the copy stored locally on the desktop PC 100. Other users may not modify the database files on the desktop PC while the communication link remains open, preventing multiple users from making changes to the file at once.

It is also possible, and preferable to have the facility of allowing a mobile user to communicate site-specific information back to a central server or repository. Autodesk, Inc. has developed the OnSite technology that allows a field technician to carry a portable handheld computer into the field and visualize a Geographic Information System (GIS) database of street maps. The field technician may then place survey information within the database and transmit the information to a server over a wired or wireless link. The present embodiment extends this concept significantly in that the current invention allows for 3-D physical environment information to be sent into the field, and also allows for complex communications network information and measured and predicted performance data to be viewed, manipulated, stored and transmitted back to another computer over a wired to wireless link. In the preferred embodiment, a position-tracking device may be attached to or incorporated in the portable handheld computer 102 so that a user's movements within the environment may be tracked and displayed. Using such a system, a field technician will know precise location information while navigating through an environment. Some examples of position-tracking devices include Global Positioning System (GPS) antennas, laser range finder scanners, tilt sensor based dead-reckoning systems, or some other positioning device known now or in the future. Interface boxes 104

and 106 allow this information, as well as other data, to be transmitted between the portable hand held computer 102 and the server computer 100. For example, after the technician makes changes on the portable hand held computer 102, this information could be used to update the computerized model of the communications network on the server 100. Alternatively, files of building information, equipment information, etc., might be retrieved from the server 100 by the portable hand held computer 102 on an as needed basis.

There are many computer aided design (CAD) products on the market that can be used to design a computerized model of a communications network. Some of the major prediction and simulation tools available are: WiSE from Lucent Technology, Inc., SignalPro from EDX, PLAnet by Mobile Systems International, Inc., TEMS from Ericsson, Virtutech Simics, CACI Products Co.'s COMNET Predictor, Scientific and Engineering Software, Inc.'s SES/Strategizer, and Make System, Inc.'s NetMaker XA. In a preferred embodiment, SitePlanner® from Wireless Valley Communications, Inc. is used as a CAD tool to predict performance of a communications network system; however it should be understood that other design tools may also be used in the practice of this invention.

With advancements in portable handheld computing power, enhanced prediction and simulation capabilities may be possible on a portable handheld computer. The desktop PC running SitePlanner® or some other prediction software could additionally be a collection of computers used in parallel to improve calculation speed. In the present embodiment, the software on the portable handheld computer can send



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The present embodiment also allows for a field engineer or

The present embodiment also allows for a field engineer or

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technician to enter a site and actively report their location while collecting data. Referring now to Figure 10, in the present invention, a user operating a portable hand-held computer 300 may attach a communication system measurement device, such as a wired or wireless network

5 transceiver, a cable integrity tester, a signal quality measurement device, a bit error rate or data throughput detector, or some other measurement tool 302 known now or in the future. In the present embodiment, specific examples of measurement devices that may be attached include, but are not limited to, the ZK-Celltest SAM with cellular phone, the Wireless

10 Valley Communications, Inc. WaveSpy radio scanner, the Anritsu SiteMaster MS2711 handheld spectrum analyzer, a Berkeley Varitronics Systems, Inc. Fox radio receiver, and a wireless Palm Modem. The measurement tool may be connected by an interface cable 304 to the interface port 60, or by other suitable wired or wireless connection.

15 Having connected a communication measurement device 302 to a portable handheld computer 300, the preferred embodiment will guide the engineer through a series of steps before beginning measurement collection with the communications device. The user should input specific device parameters so that the measurement device may be set up properly.

20 Some measurement equipment devices have real-time interfaces, where the portable handheld computer can interface directly to the measurement device and potentially directly select options and parameters for the measurement equipment. Other measurement devices require the user to select options manually with an interface on the device itself. If a real-

25 time interface is present on the measurement device 302, the options and parameters pertaining to the selected measurement device may be

transmitted over the communications link between the portable handheld computer and the measurement device. In another embodiment, as is shown in Figure 10, an RS-232 serial interface cable 304 is used to connect the portable handheld computer 300 with the measurement device 302; however, one skilled in the art would observe that other communications links could be used such as USB serial, FireWire, a BlueTooth wireless system, or some other communications link known now or in the future could also be employed. In the embodiment shown in Figure 10, RS-232 serial communications are preferably managed using the Palm OS's New Serial Manager specified as part of the Palm OS Programmers Companion. The New Serial Manager handles low-level implementation details for communications between the software running on the portable computer 300 and the serial port on the portable handheld computer 300. The Palm OS software development kit implements function calls to send data over the serial port using the New Serial Manager. Further details on the Palm OS New Serial Manager and how PalmFielder uses the serial connection are detailed as part of the Palm OS software development kit reference document. Once a measurement device has been connected to the portable handheld computer and the user has specified the desired options and parameters for the device, data collection and remote monitoring by another server or client may begin. When using a measurement device equipped with a real-time interface, data collection can be performed in the background while the user navigates within the building or places the measurement device in a fixed location. With some measurement devices, data will be stored in the WPD file at all times using a time or position code to indicate when or where the

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data was collected. The WPD specification indicates how measurement data is stored in a WPD file.

As disclosed in the co-pending application 09/221,985, the complete contents of which has been incorporated by reference, the user may input the current location into the portable hand-held computer 300 using several methods. In a marker mode, the user taps or clicks at the current location and a single measurement is made using the attached testing device. In a track mode, the user indicates the current position by clicking or tapping on the display, then walking in a straight line at constant velocity, and then clicking or tapping to indicate the stopping position. The data collected during the traveling period may then be averaged according to user specified options and stored within the database at evenly distributed points along the path either by using a set time interval or unit distance.

In an "Auto" mode, the user attaches a position-tracking device such as a GPS antenna, a laser range finder, a tilt sensor based dead-reckoning system, or some other tracking device that can detect position or change in position or motion known now or in the future. As the field user moves around in the environment, measurements collected from a receiver are correlated with position information collected from the attached tracking device. Such a system can be used to record large amounts of data with minimal user interaction needed. As a user of the hand held client collects measurement data within the environment, the collected data may be transmitted in real-time or near real-time to a remote server computer or another client, and the measured data is then displayed on a 3D model of the environment at the remote computer. The data is also

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logged and processed at the remote computer for archiving and analysis.

Measurement data stored in the WPD file can be displayed directly on the building map by using a colored or patterned marker such as a circle, rectangle, asterisk, or some other shape at the position the data was recorded. In the case where prediction or simulation data is also available for the building, the user preferably may choose to display the prediction or simulation data along side actual measurements. The current embodiment also allows the user to show markers and statistics directly on the building drawing indicating differences between predicted or simulated data and actual measurement data.

An important component of the SitePlanner® tool suite is the Optimatic® module, where measurement data is used to optimize both the prediction model and the prediction model parameters. The portable system contemplated by this invention can be adapted to be used to optimize the prediction model and prediction model parameters on-site on the fly at the discretion of the engineer. Figure 9 shows a system for transferring measurement data over a wired or wireless communications medium. Using the communication link mentioned previously, where a desktop PC server running SitePlanner® or other capable software is connected via a wired or wireless communications medium, the collected measurement data may be sent to the desktop PC for optimization of the prediction or simulation model or model parameters. Once the desktop PC has optimized the prediction or simulation model or model parameters, updated predictions are made, and the new predictions are sent back to the portable handheld computer over the aforementioned communications link. Given more processing power on the portable handheld computer,

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